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Title: LANL Ionospheric Interests

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Los Alamos
NATIONAL LABORATORY
EST. 1943

LANL ionospheric interests

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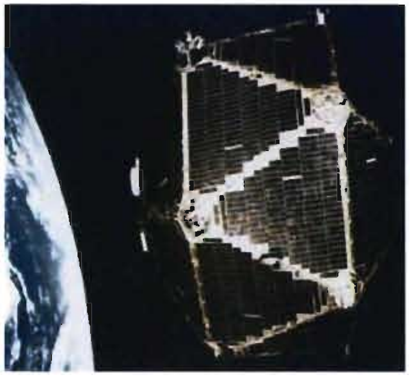
Los Alamos has a long heritage of space-based RF transient sensors

Operational Sensors

Vela W-Sensor



GPS IIA/IIR W-Sensor

GPS IIF V-Sensor

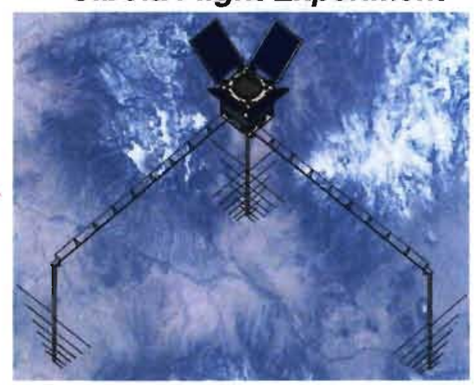
GPS III V-Sensor

R&D Sensors

ALEXIS/Blackbeard

FORTE

Cibola Flight Experiment



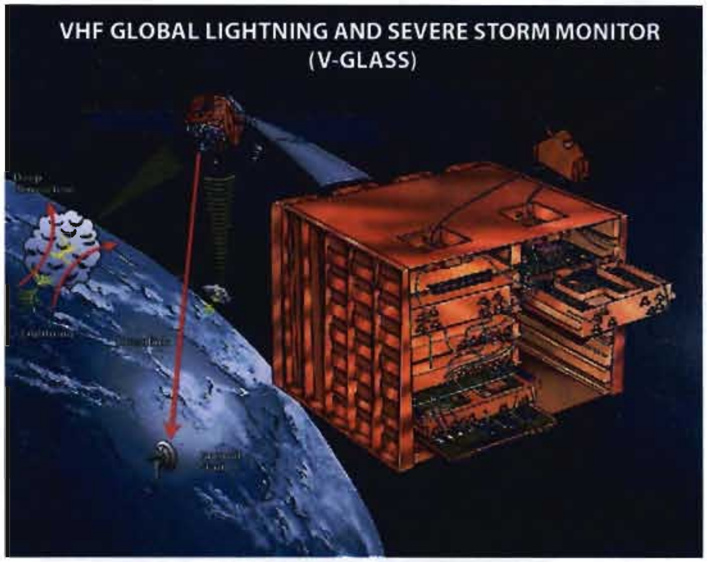
LANL On-Orbit EMP Sensor Program

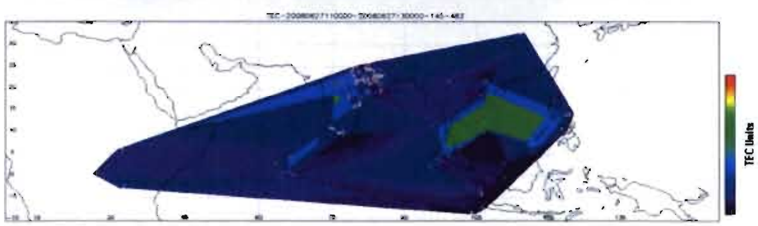
- **LANL has multiple roles in EMP Sensor design, production, certification, and operation for the US Nuclear Detection System (NDS)**
- **NDS EMP sensors are hosted on GPS satellites**
- **Beginning with GPS Block IIF, LANL has designed and produced the EMP sensor payloads for GPS**
  - IIF EMP sensor is "BDV"
  - IIA and IIR EMP sensors are "WSRP" and "BDW" respectively
- **Payloads have some capability for detection of terrestrial lightning discharges and on-board discharges**
  - Lightning detections provide information about path Total Electron Content (TEC)
  - On-board discharges provide information about the space environment

GPS IIF SV-01 Launch, 27 May 2010

GPS/USNDS Global Total Electron Content Mapping

POC: Dave Suszcynsky, LANL, dsuszcynsky@lanl.gov, 505-665-3119





Example of a TEC contour plot. Symbols show 145 detected lightning events (483 TEC measurements) used to produce contours.

Global TEC mapping via lightning/beacon detection using existing and planned US Nuclear Detection System (USNDS) VHF radio receivers aboard the Block IIR/IIF GPS satellite constellations

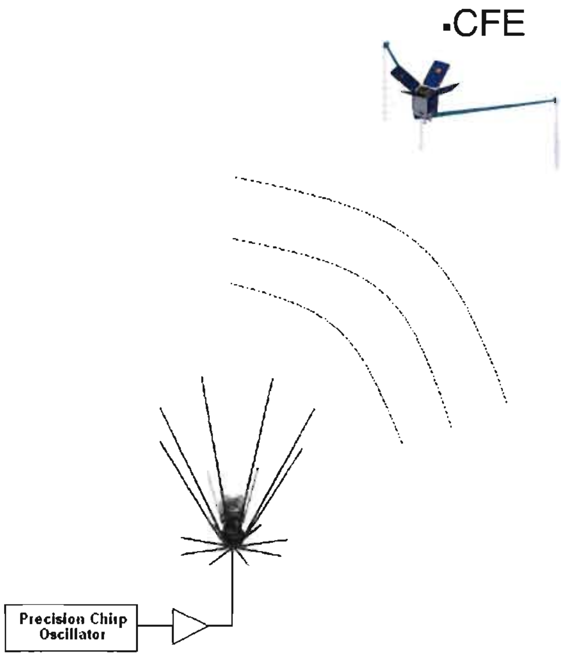
Current capability

- Small TEC uncertainty + high location accuracy (actual values classified)
- 8 GPS sats, 1 NM ground station (GS) → variable W. hemisphere coverage
- 6 TEC measurements/min. averaged over W. Hemisphere
- No real-time data distribution network

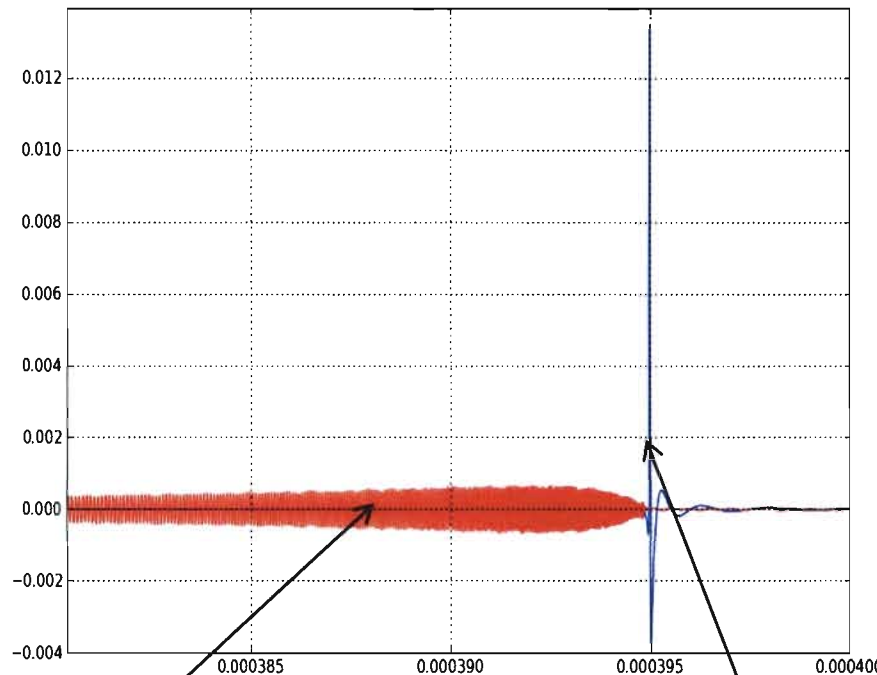
Future capability

- 24 satellites by 2014 (per GPS launch schedule)
- 3 more GS, including RT data distribution (funding being pursued) → global, 24/7, RT coverage by 2014
- Expect≈60 TEC measurements/min. averaged over globe

Scintillation studies with LANL CFE



Ground-based Calibration Transmitter



Synthetic ionospheric chirp

Impulse reconstruction

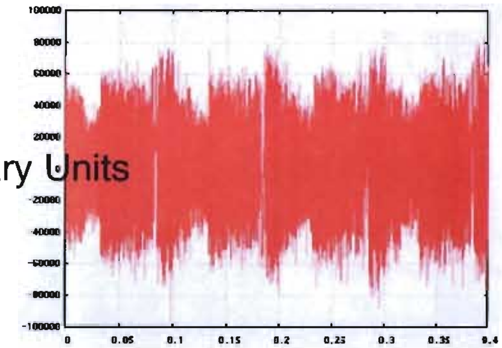
Katko, Light & Colestock (2011) in progress

CFE Narrow Band Recorder – Time Domain Signals

Matched Filter Deconvolution

- On orbit received signals

Arbitrary Units



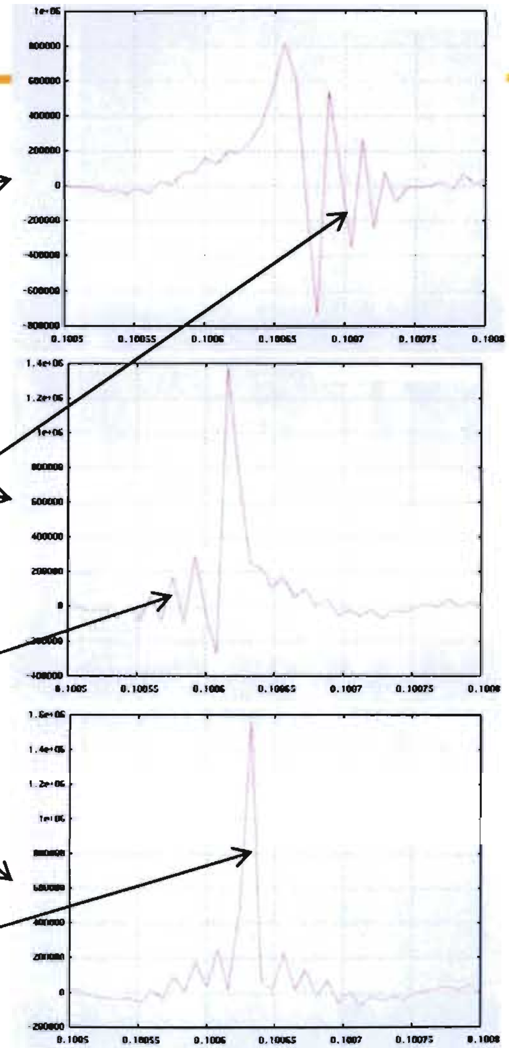
Time (sec)

6 MHz Sampling Rate

Slew rate:3.140 MHz²

Slew rate:3.145 MHz²

Slew rate: 3.1414 MHz²



Time (sec)

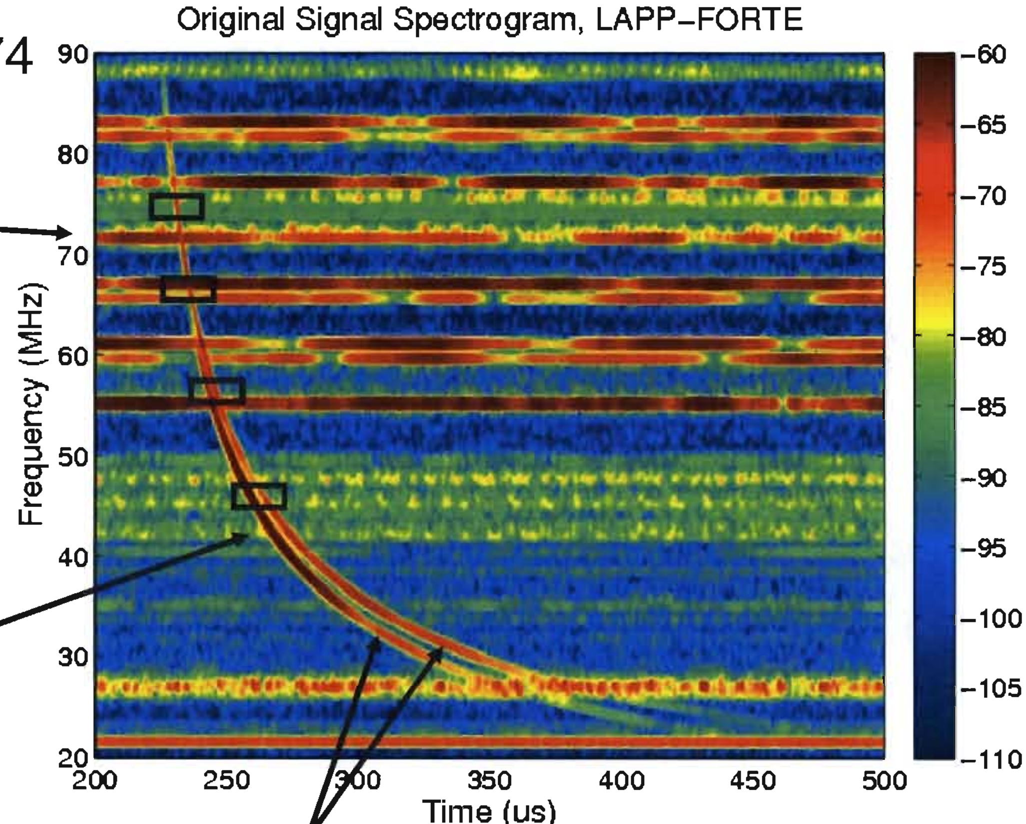
Phase oscillations sensitive to TEC

Expected Differential TEC Resolution:
0.01 TEC Units

Precision timing yields measurement of Coherence Bandwidth

LANL COHSIG:

LAPP shot, FORTE, TEC=74

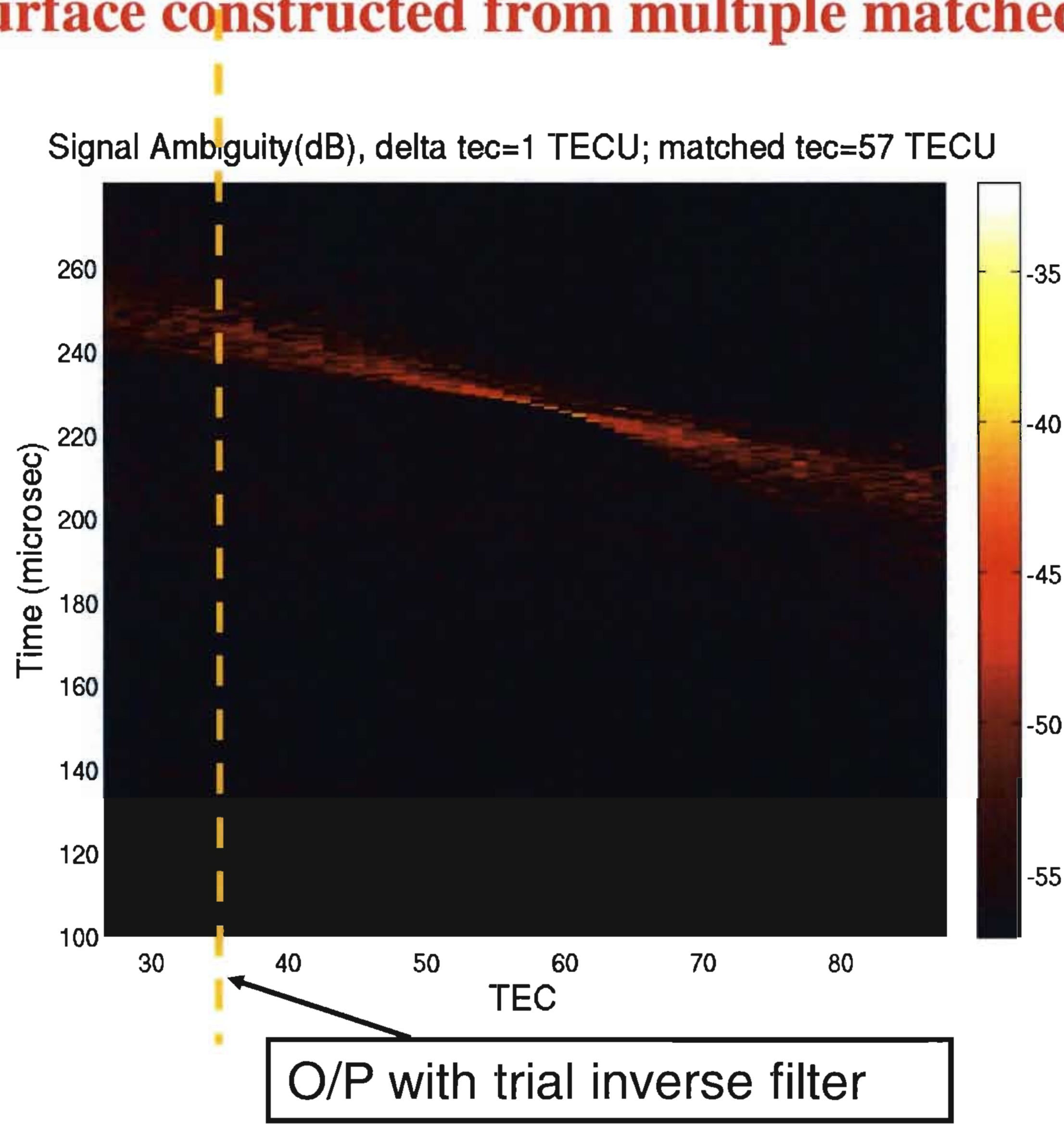


Anthropogenic noise – carriers+

Impulsive signal dispersed in frequency and time

X and O mode splitting

Ambiguity surface constructed from multiple matched filters



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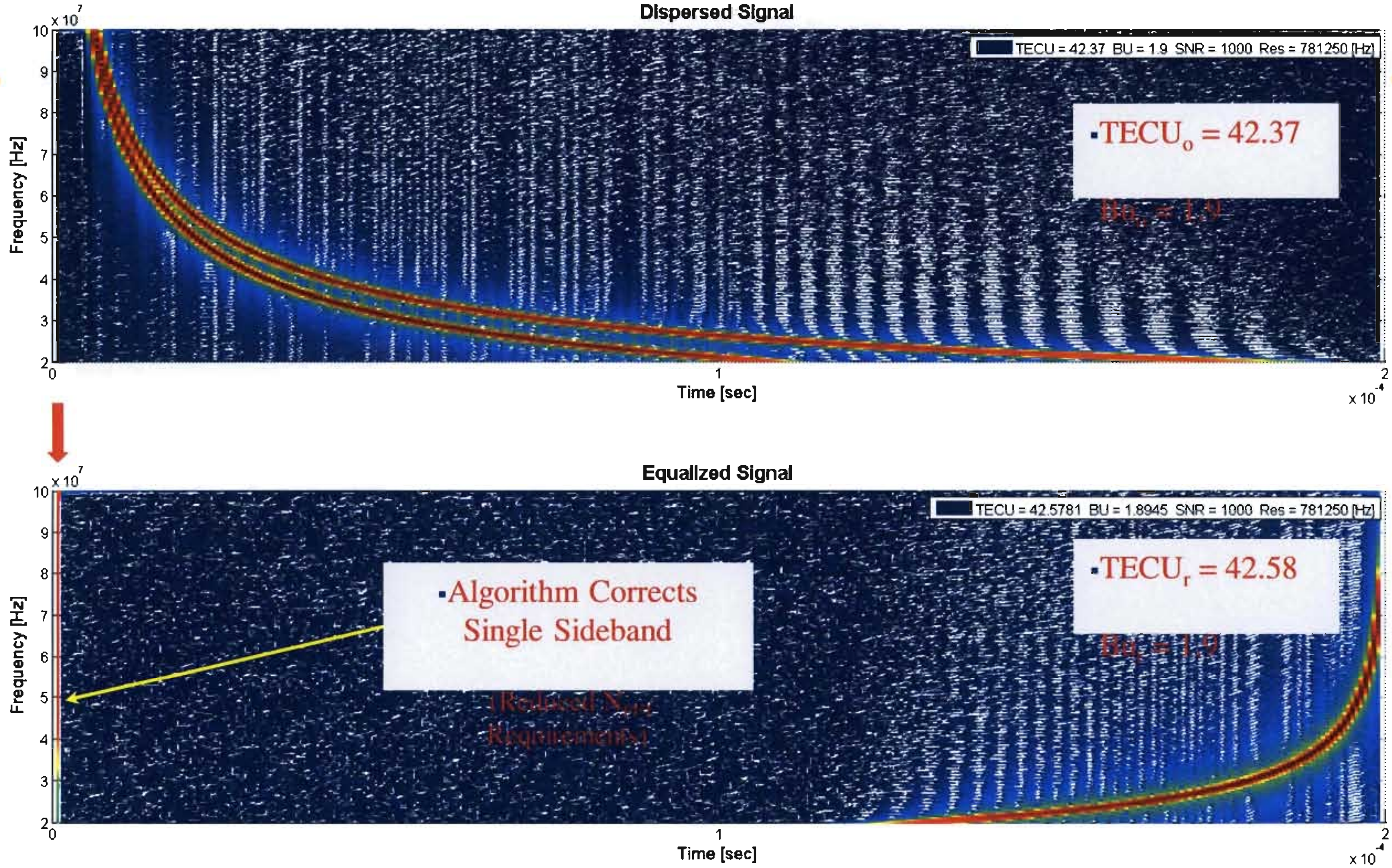
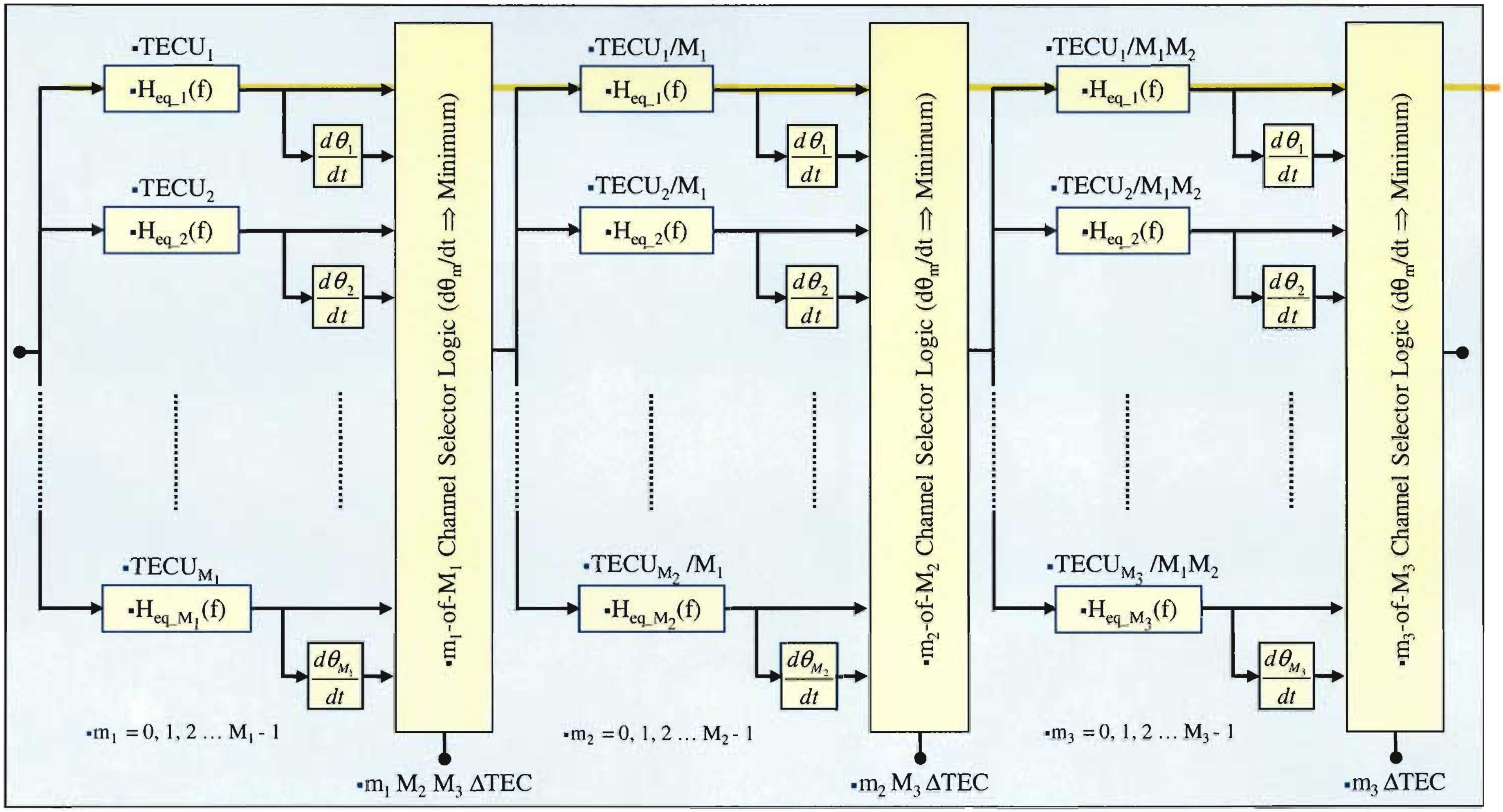
Example: *8+8+8* Cascaded SP Equalizer Response (2^{nd} & 3^{rd} Order)



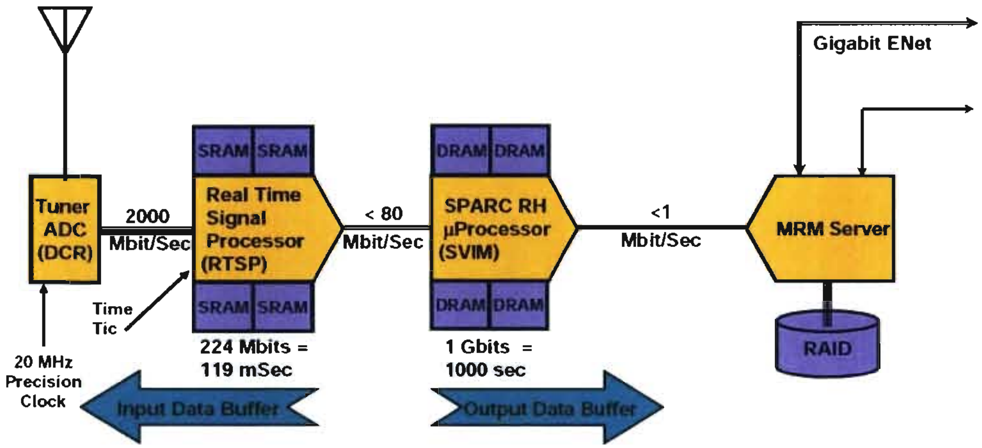
▪BW = 20-100 MHz, T_s = 5 ns, N_{FFT} = 40k (T_w = 200 μs)

MxN Cascaded SP Architecture: 20 Segments = 8+8+4 $\Rightarrow$ $\Delta TEC = TEC_{max}/256$



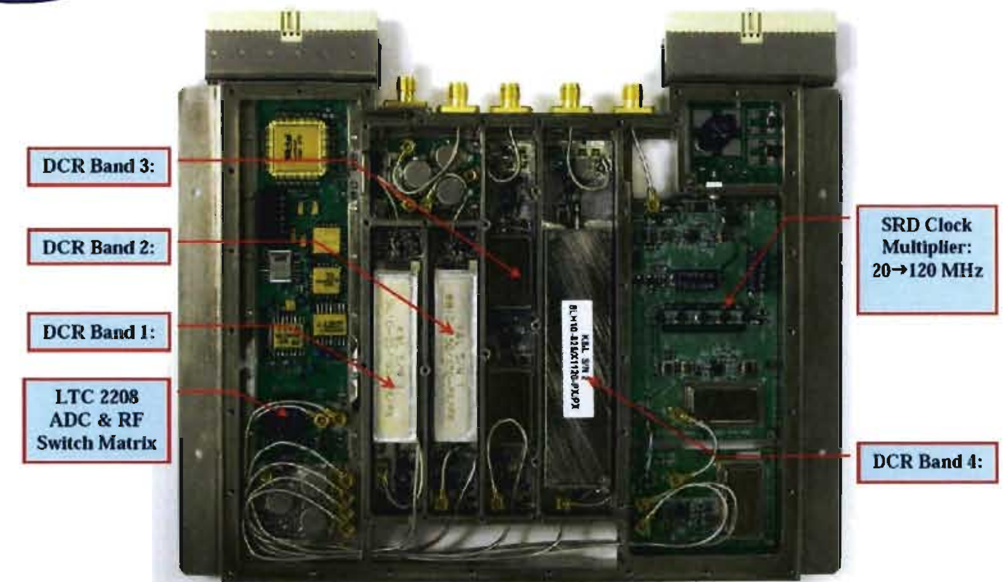
▪Resolution: $\Delta TEC = \dfrac{TEC_{\max}}{M_1 M_2 M_3}$ ▪Segments: $M_1 + M_2 + M_3$

Ongoing hardware development: MRM next-generation RF sensors for space



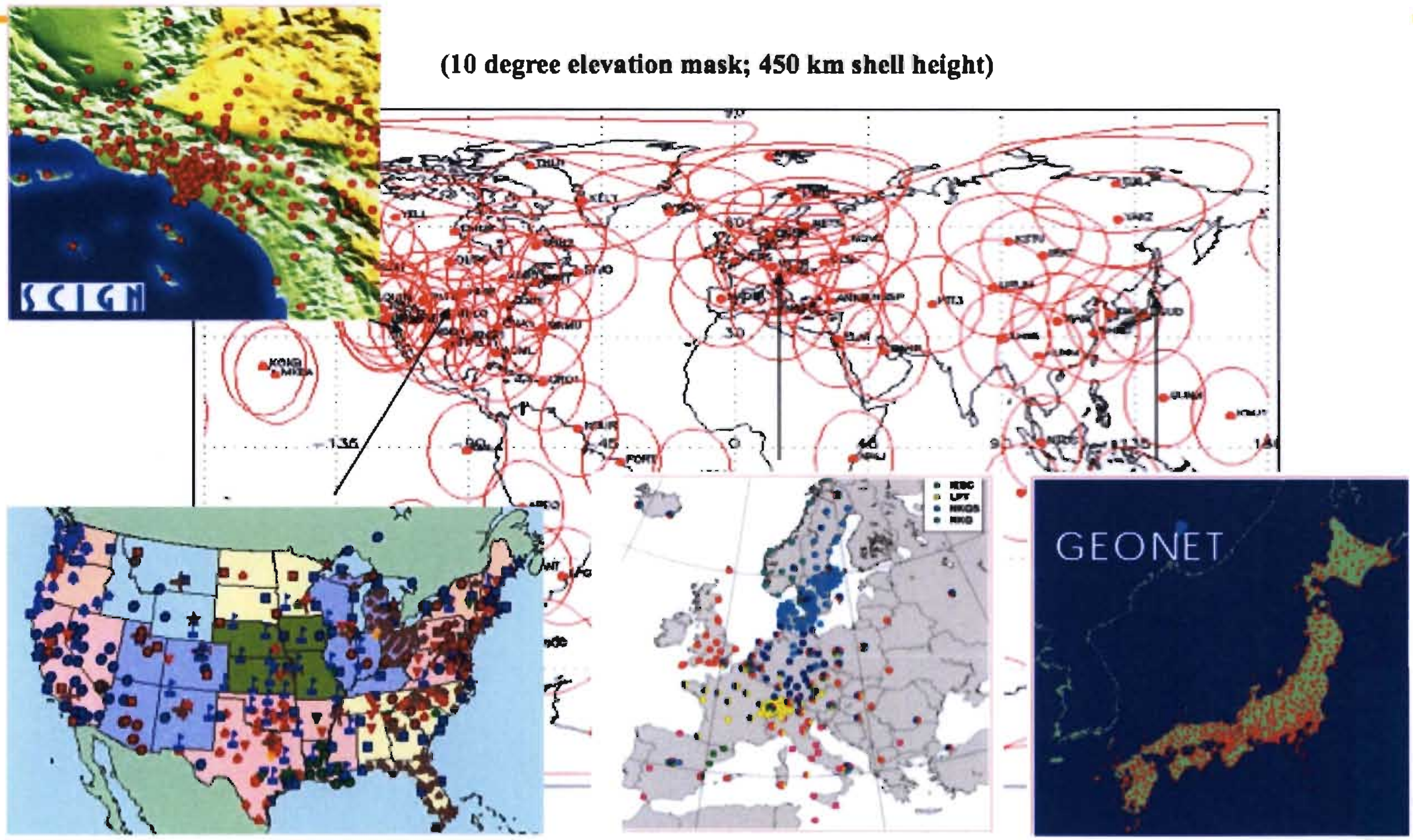
- Direct conversion Rx
- Software-defined radio

- "supercomputing-in-space"
- COTS technology + fault/upset detection/remediation



Coverage of Daily IGS Network and Regional Networks

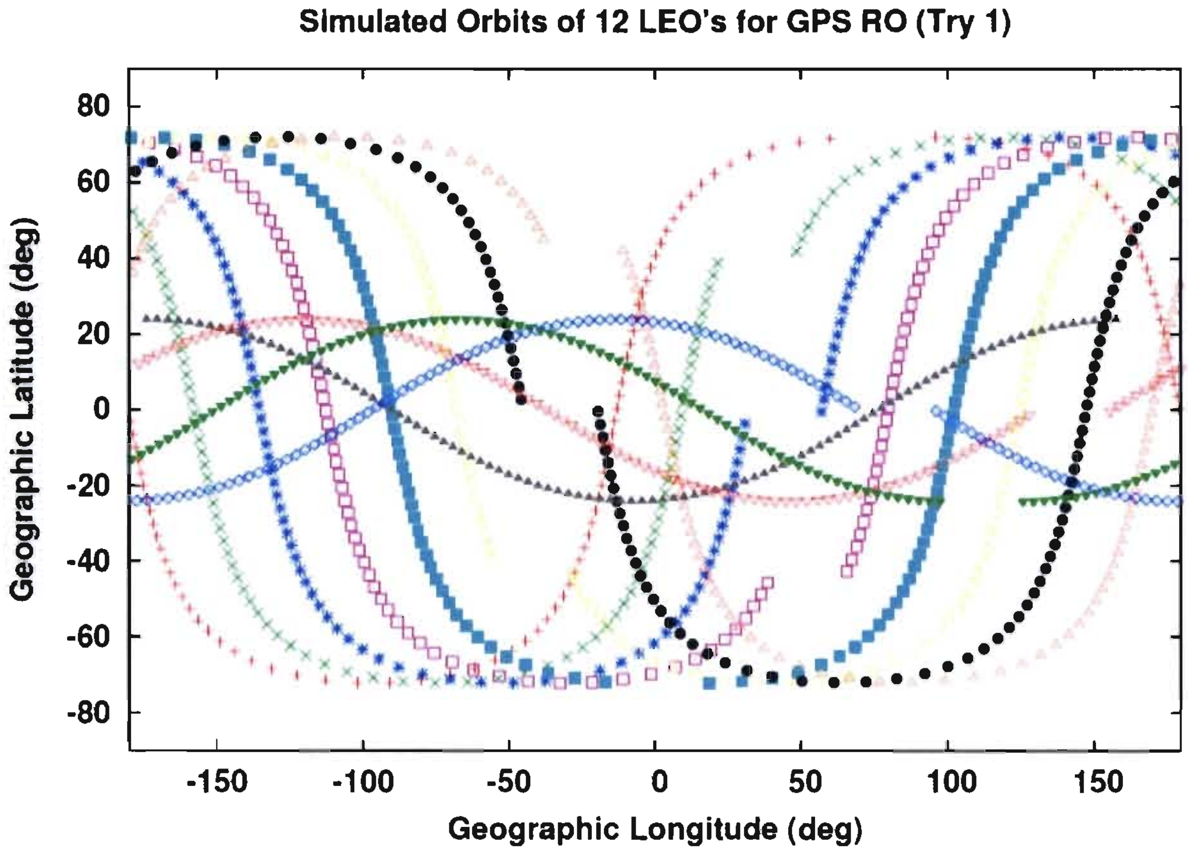
(10 degree elevation mask; 450 km shell height)



COSMIC 2 (JPL simulation)

Simulated constellation

- 12 satellites
- $I = 72°$ (8)
  $I = 24°$ (4)
- RA's of ascending nodes are evenly spaced over 180°
- Orbit height ~800 km
- Orbit period ~101 minutes
- Eccentricity . 0033

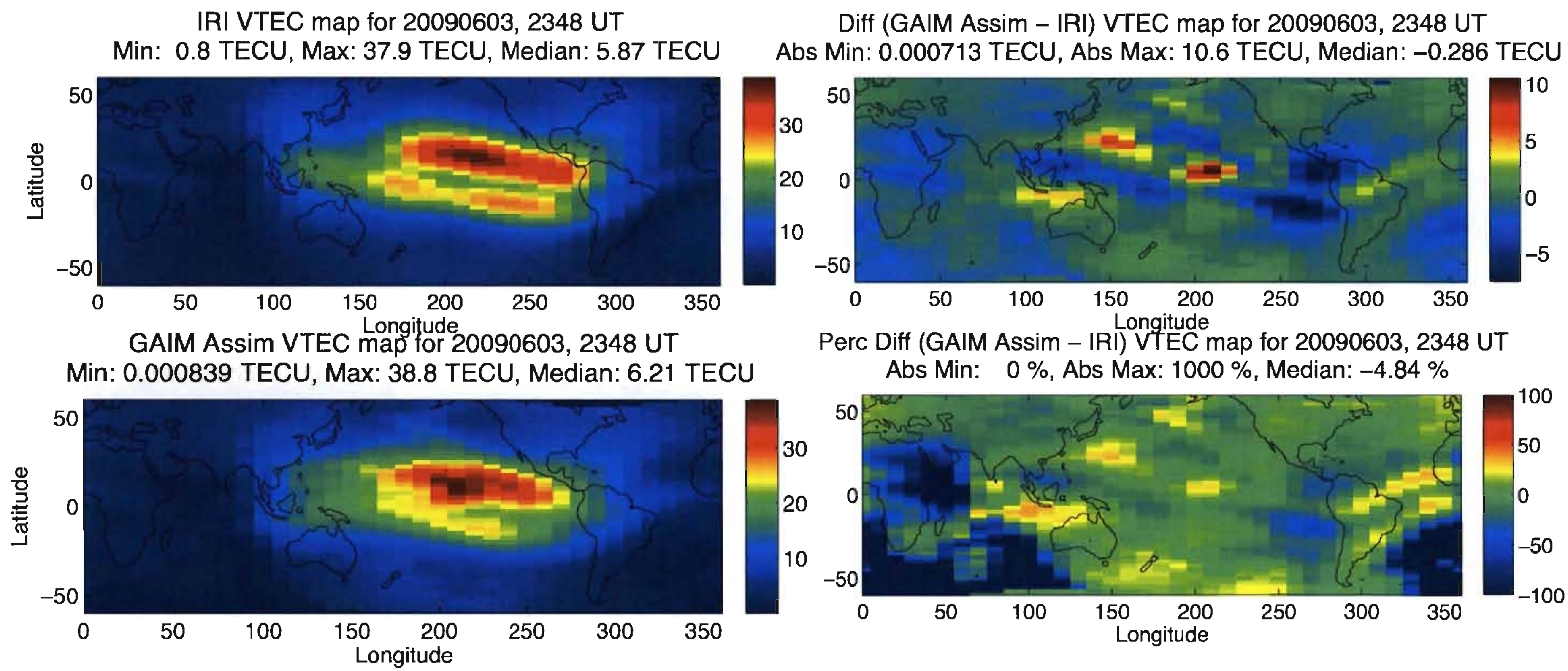


- Pi et al (JPL), Observation System Simulation Experiments Using JPL-USC GAIM, presentation COSMIC Workshop, Boulder, Colorado, October 28, 2009

LANL CONtinuous SIMulator (CONSIM)

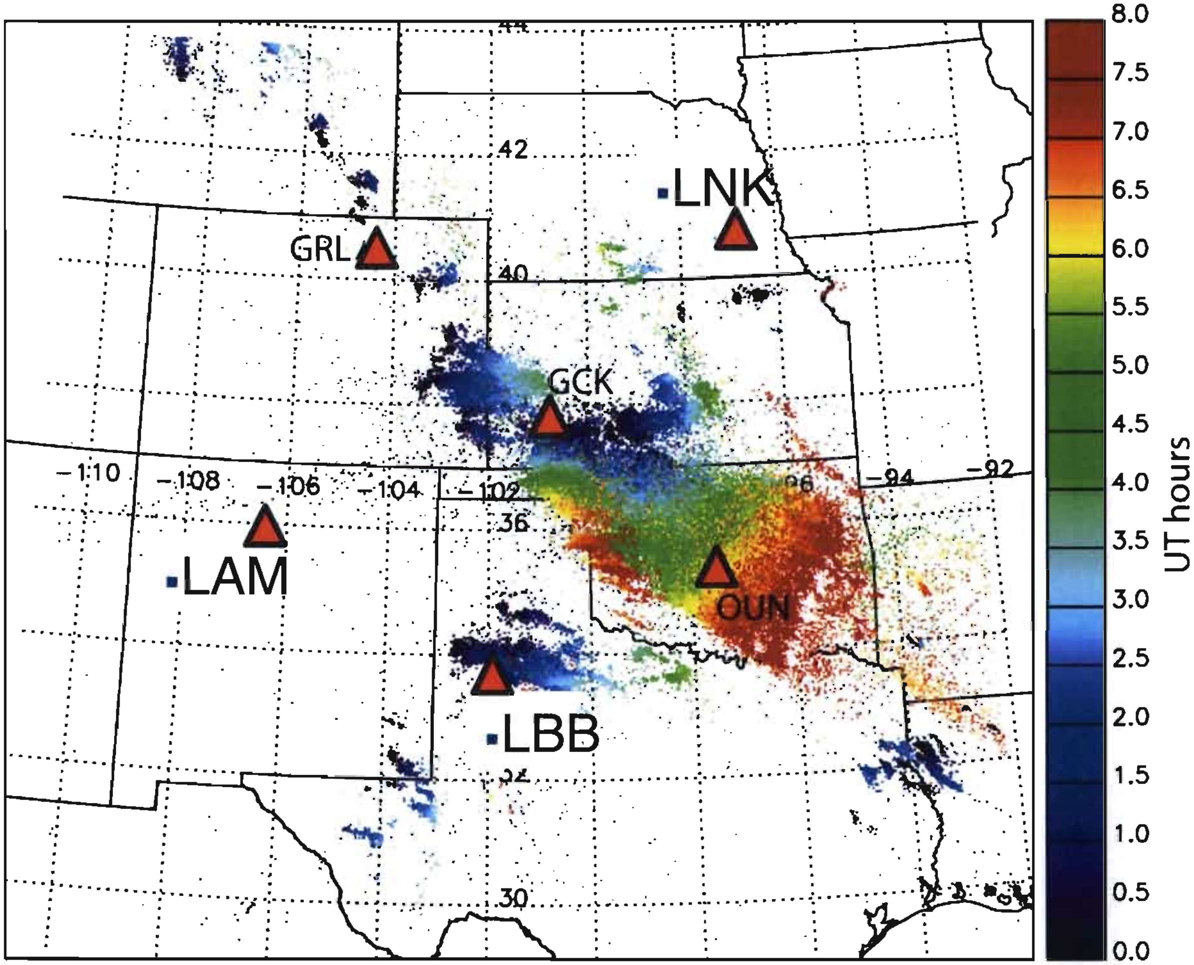
- **Provides simulation capability for Los Alamos sensors flying on a variety of satellites**
- **CONSIM functionality used for IDA_SE: robust, configuration-controlled version of IRI-2007 supporting calls to quickly give N_e**
- **While IRI-2007 only provides N_e at an array of altitudes, CONSIM had been modified to allow integration along a line to obtain TEC**
- **Creating simulated TEC measurements with CONSIM:**
  - input ground or LEO satellite GPS receivers locations and the GPS constellation locations at times of interest
  - CONSIM determines valid lines-of-sight
  - CONSIM integrates N_e between GPS satellites and receivers
  - Create a file in the form required for GAIM input data (complete for ground-based IGS GPS receivers)

Sample plots for evaluating accuracy of GAIM output: VTEC comparison of 'truth' and GAIM assimilation

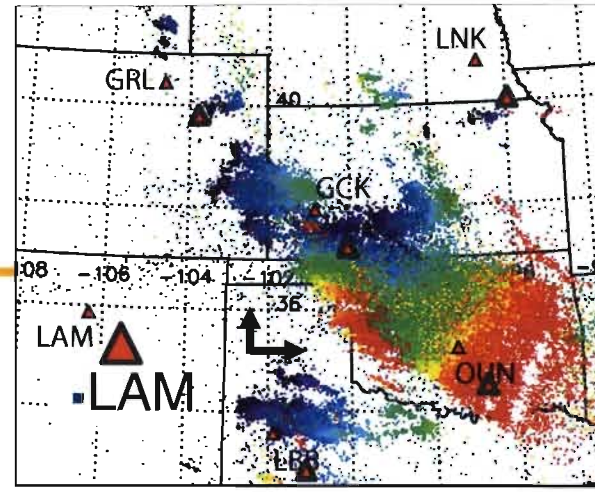


Probing the D-layer near thunderstorms by using lightning as VLF/LF radiation source

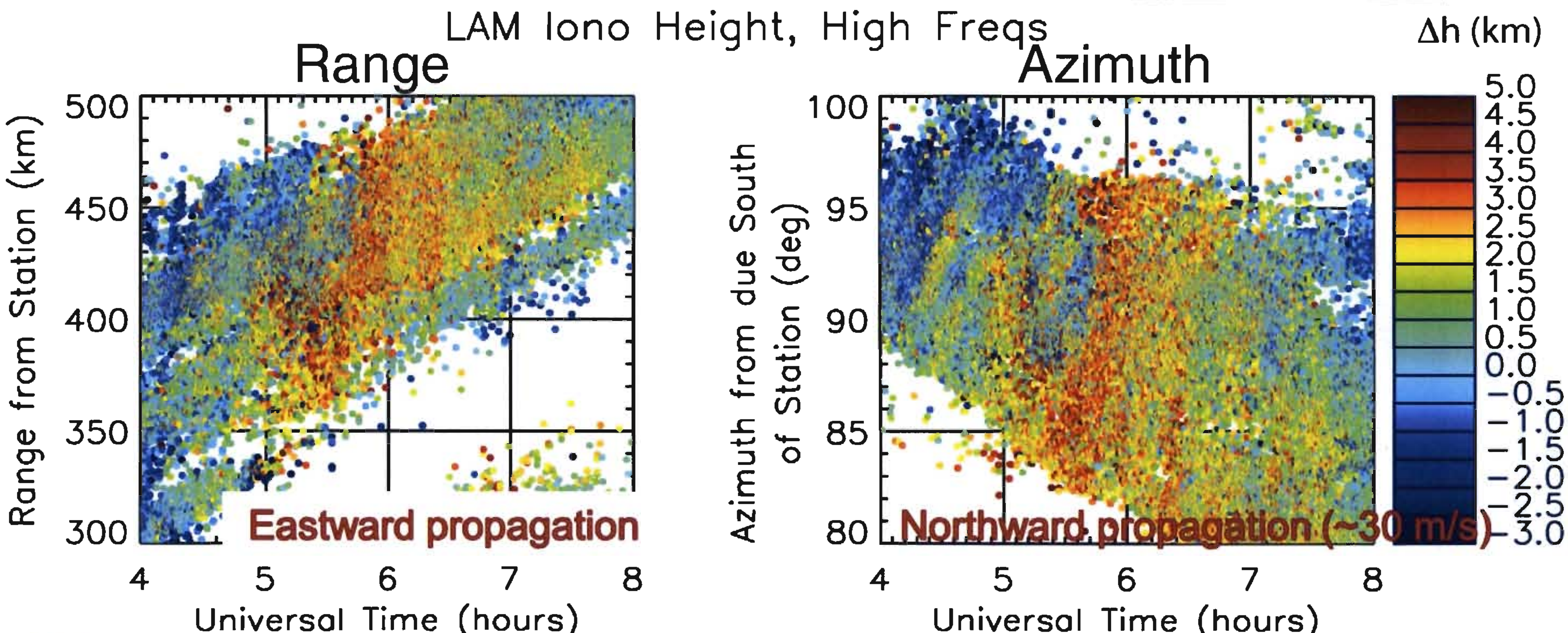
- Each lightning impulse probes the ionosphere midway between source and station
- Technique presented in *Lay and Shao, JGR,* ***116****, A01317 (2011)*
- Case Study
  - 17 June 2005
  - 101,552 -CGs
  - Data from LNK, LBB, and LAM shown here



Height fluctuations in range and azimuth from LAM

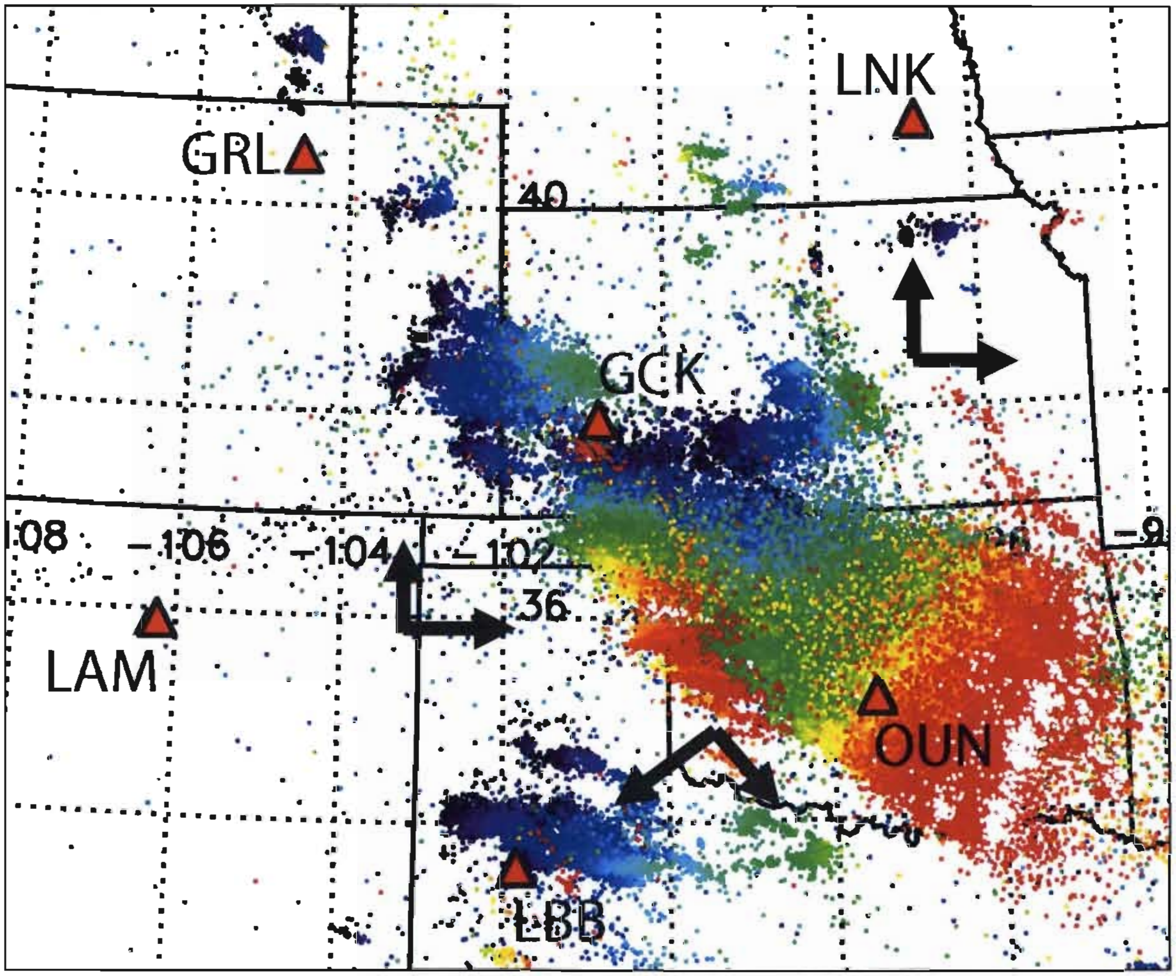


Lay & Shao (2011)

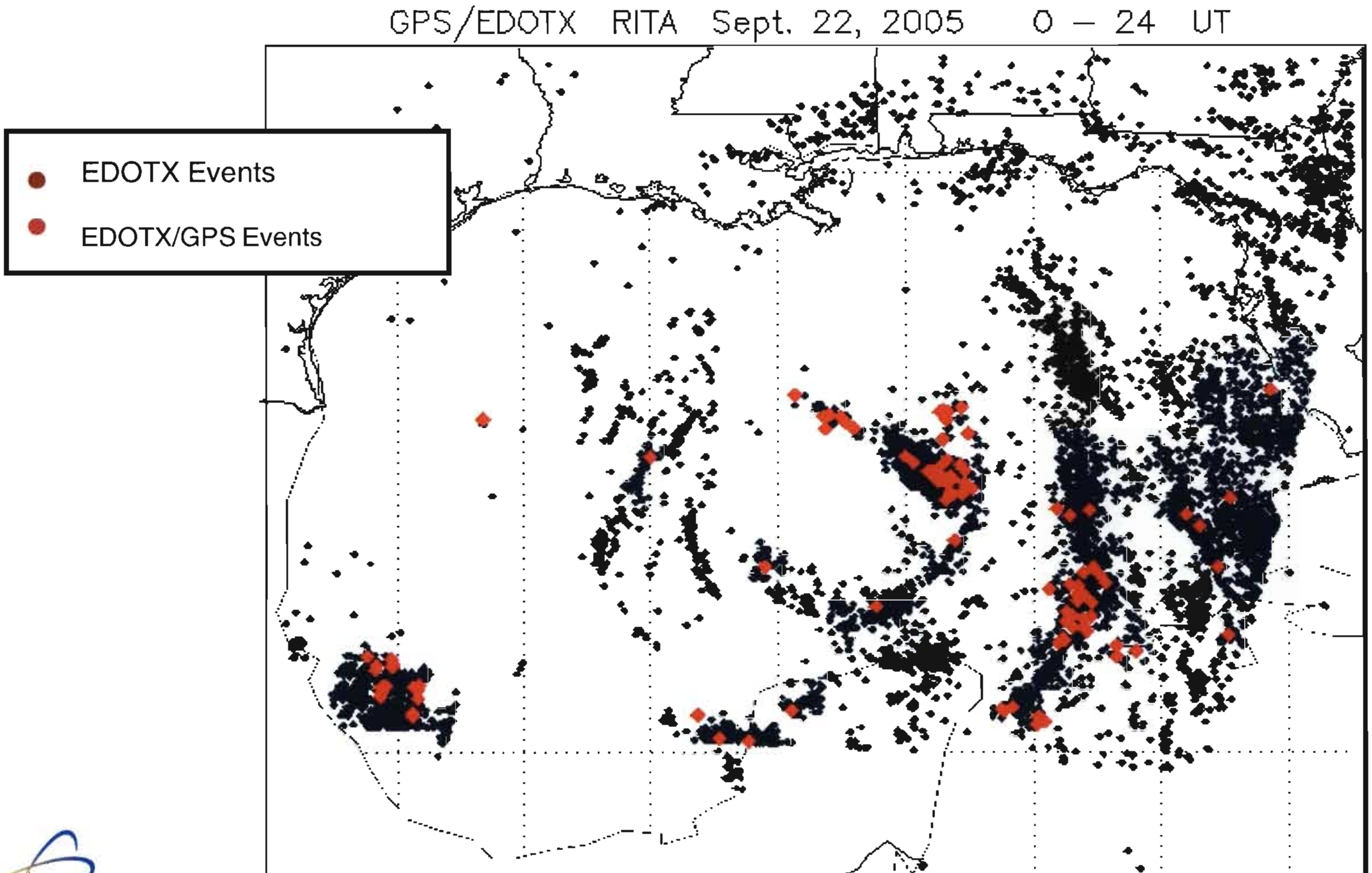


D-layer fluctuations (Lay & Shao, 2011)

- Multi-station measurement provides evidence for propagation away from storm in D-layer.
- Background east-ward waves
- LAM 'upwind' from storm, so back-ground wind dominates
- LNK + LBB also detect background eastward component



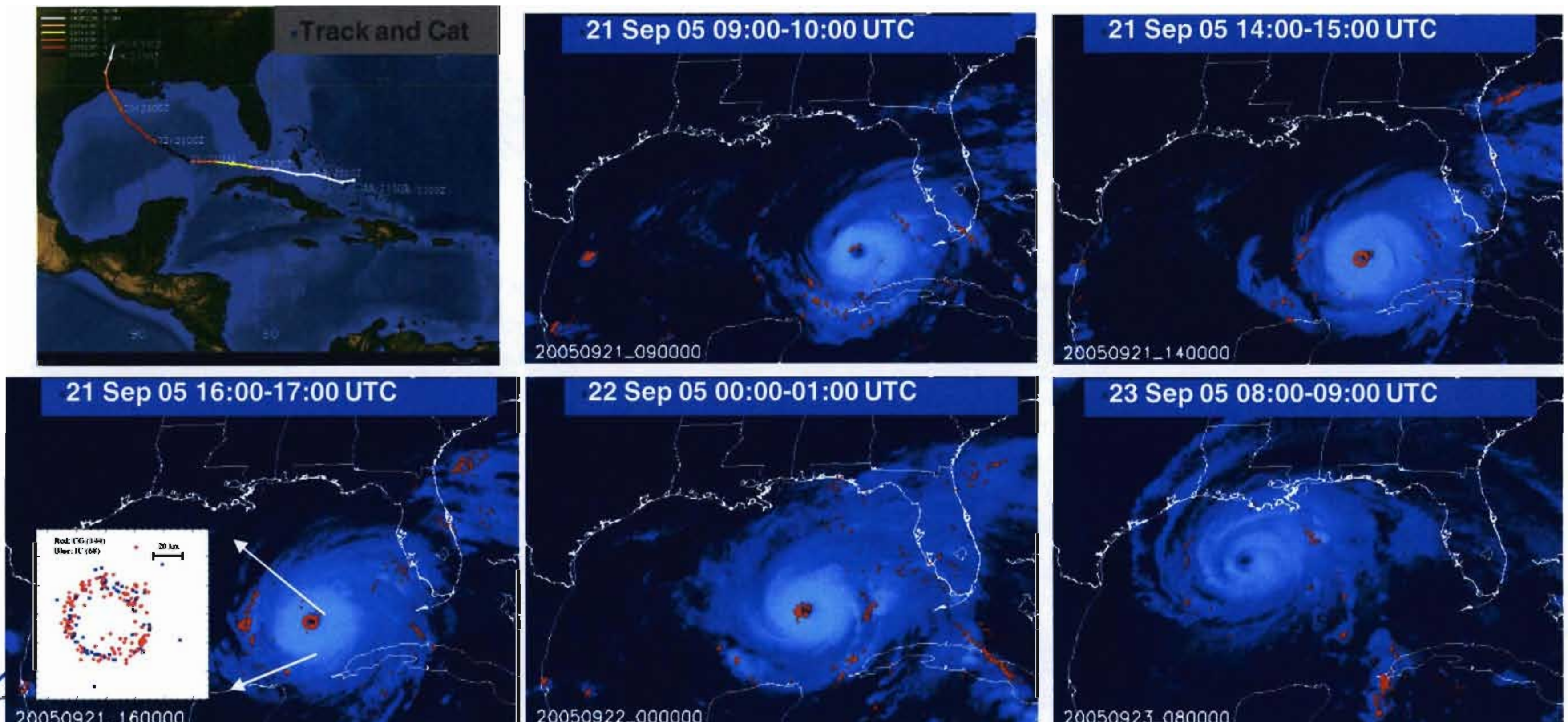
Lightning from Hurricane Rita was also seen from space



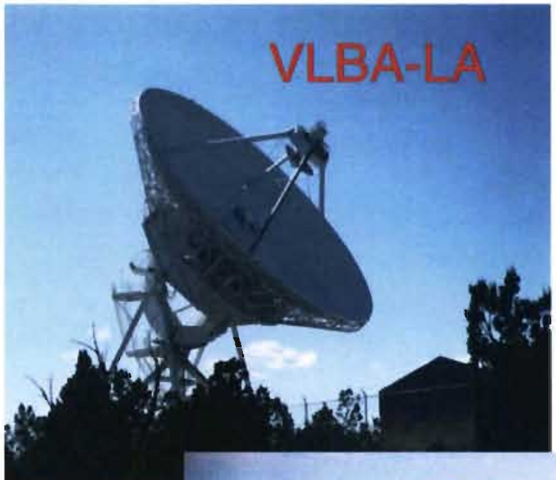
Lightning activities of Rita

(1) Start to see eye-wall lightning at Cat 3. (2) Eye-wall lightning intensifies while Rita progresses from Cat 3 to 5; eye-wall lightning decreases when Rita decays. (3) Normal rate of rainband lightning; rainband lightning not associated with storm intensity. (4) Rita intensified from Cat 3 to 5 much faster than Katrina, and produced much more eye-wall lightning

•*Shao et al., Eos, 86, 42, 18 Oct. 2005*

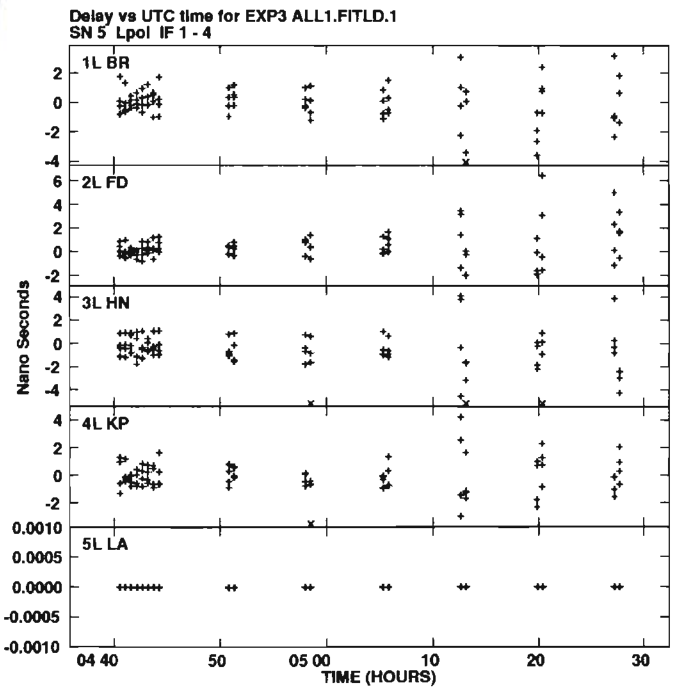


MAGI: active interferometry at X-band using sparse aperture



Very Long Baseline Array

Differential delay error ≈ few ns after ionospheric and tropospheric correction



Re-visit ionospheric studies with the Expanded Very Large Array?

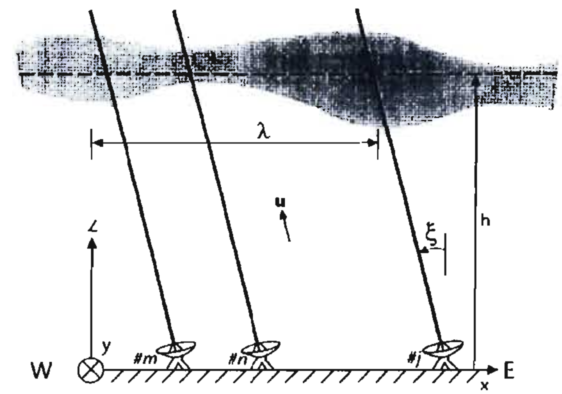
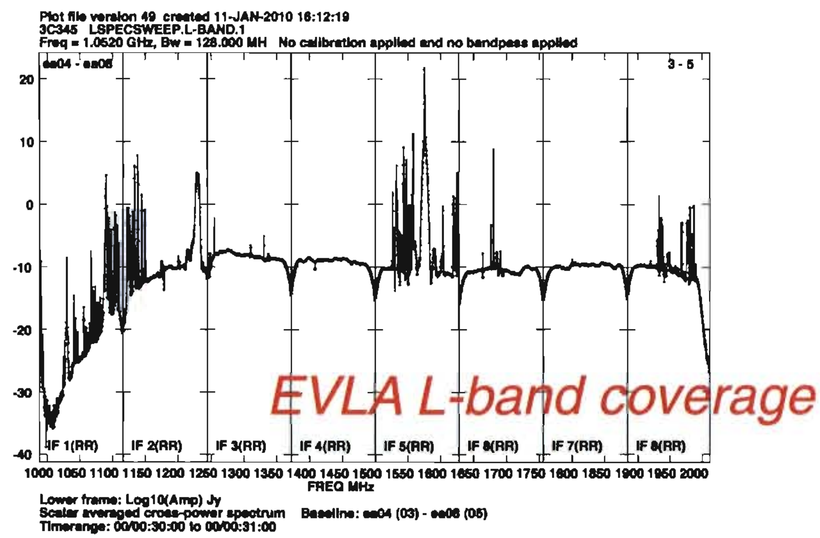


Fig. 1. Schematic of radiotelescopes ranged along the x-axis (eastward) in the vertical/EW plane. The unit vector u points toward the radiosource. The x-dependent TEC is represented by the shaded undulation at mean height h. The dominant wavelength in the undulation is λ



Initial work done by Jacobson & Erickson (1992) Astron.Astrophys. **257**, 401 … but EVLA has much improved sensitivity and coverage

End